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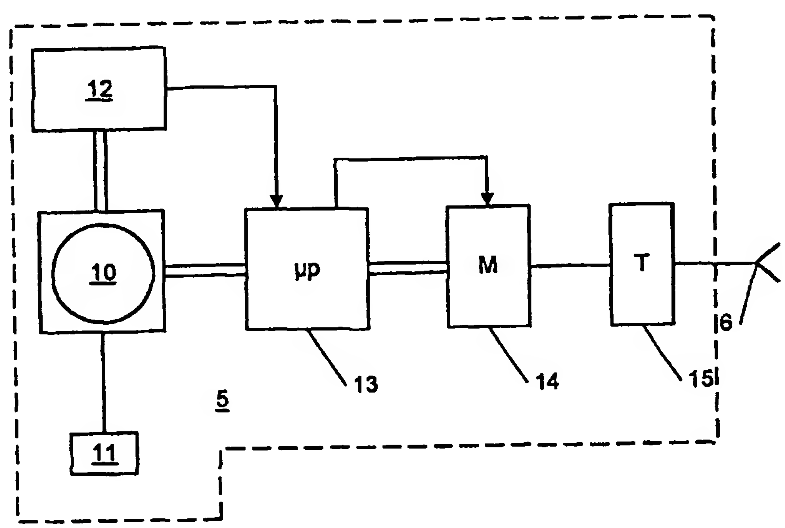
(54) Title: A DEVICE FOR MONITORING AN OPERATION OF AN ELEVATOR CAR



(57) Abstract: A device for monitoring the operation of an elevator car, said device comprising a measuring unit, provided for measuring a parameter value of a parameter, indicating at least a vertical movement of the elevator car, and a processing unit, provided for processing said parameter value, said measuring unit comprises a buffer memory, provided for temporarily storing a first set of successively measured parameter values, said device further comprises a recognition unit, provided with a local memory for storing a second set of parameter values, identifying a travel of the elevator car, said recognition unit being further provided for retrieving said first set from the buffer memory and for performing a matching operation on the first and second set and for generating a trigger signal when said first set matches with said second set, said recognition unit being connected with said processing unit, which is provided for retrieving said first set from said buffer memory under control of said trigger signal.

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A device for monitoring an operation of an elevator car

The present invention relates to a device for monitoring the operation of an elevator car, said device comprising a measuring unit, provided for measuring a parameter value of a parameter indicating at least a vertical movement of the elevator car, and a processing unit, provided for processing said parameter value.

Such a device is known from the German patent No. 42 17 587. With the known device, the acceleration of the elevator car is measured as a parameter, indicating the vertical movement of the elevator car. The measured parameter values are then transmitted to a processing station for further processing. The monitoring is however not continuously performed, as the device is only temporarily installed in the elevator car.

A drawback of the known device is that it is not suitable for a substantially continuous monitoring of the elevator car. If the device would be used for continuous monitoring, the amount of data to be transmitted, would be so considerable, that the communication costs would be prohibitive. Moreover, monitoring from time to time is not sufficient to detect or anticipate malfunctioning of the elevator. By continuous monitoring, it becomes possible to detect symptoms of malfunctioning at an early stage and to prevent in such a manner a defect into the operation of the elevator car and avoid expensive urgent technical intervention.

It is an object of the present invention to realise a device for monitoring an operation of an elevator car wherein the mentioned drawbacks are mitigated.

A device for monitoring an operation of an elevator car according to the present invention is therefore characterised in that said measuring unit comprises a buffer memory, provided for temporarily

storing a first set of successively measured parameter values, said device further comprises a recognition unit, provided with a local memory for storing a second set of parameter values, identifying a travel of the elevator car, said recognition unit being further provided for retrieving said first set from the buffer memory and for performing a matching operation on the first and second set and for generating a trigger signal when said first set matches with said second set, said recognition unit being connected with said processing unit, which is provided for retrieving said first set from said buffer memory under control of said trigger signal. By applying a matching operation on the first and second set, only those first sets, which indeed correspond to a travel of the car, are considered as relevant and are taken up by the processor. This enables to reduce considerably the amount of data to be stored and to be transmitted, and consequently reduces the transmission and/or storage costs.

Preferably, said buffer memory is a ring buffer memory. Addressing of the memory locations is facilitated in such a manner.

A first preferred embodiment of a device according to the invention is characterised in that said measuring unit comprises an accelerometer and wherein said second set comprises a number of threshold values. Accelerometers not only enable to measure the most essential movement parameters of the elevator car, but also enable to derive in an easy manner several other parameters such as the jerk, the velocity and the travelled distance.

A second preferred embodiment of a device according to the invention is characterised in that said processing unit is connected with a data transmission unit, comprising a first directional antenna, provided to be mounted on top of the elevator car, and a second directional antenna, provided to be mounted on top of an elevator shaft,

said first and second antenna being operatively connectable to each other for enabling transmission within the shaft, said second antenna being operatively connectable with a third directional antenna, provided to be mounted on an outer wall. The elevator shaft not being a most appropriate place for enabling a wireless transmission, the use of directional antennas enables to focus the transmission wave into the shaft, thus limiting considerably the reflections and improving the transmission quality.

The invention will now be described in more details with reference to the drawings, illustrating a preferred embodiment of a device according to the invention.

In the drawings :

fig 1 shows an elevator shaft with the elevator car, equipped with a device according to the invention;

fig. 2 shows schematically an embodiment of a device according to the present invention;

fig. 3 shows measurement data of the acceleration such as measured by the measuring unit, which is part of the device according to the present invention;

fig. 4 shows the jerk such as derived from the data shown in figure 3;

fig. 5 shows the velocity such as obtained from the data shown in figure 3;

fig 6 shows the acceleration and jerk signal, calculated with a predetermined algorithm;

fig. 7 shows the frequency weighting for a Z-axis whole body response to vibration;

fig. 8 shows the emission lobe of the directional antenna used in the device according to the present invention;

figure 9 illustrates a first histogram showing, for a plurality of runs of the elevator, a number of runs in function of the elevator runtime; and

figure 10 illustrates a second histogram showing, for a plurality of runs of the elevator, a number of runs, in function of a predetermined time pattern.

In the drawings, a same reference has been assigned to a same or analogous element.

As shown in figure 1, an elevator car 2, is provided to travel inside an elevator shaft 1, between the different floors of a building in which it is installed. The elevator is connected by means of a cable 3 to a drive motor 4. On top of the elevator car, a device 5 for monitoring the operation of the elevator car, is installed. It should be noted that it is not necessary to mount the device on top of the car and that it could be installed at any location on the car such as for example on the side walls, the bottom or inside the car. Mounting on top of the car is preferred if wireless communication of the recorded data is requested, as this enables to limit the distance between the device and its first antenna 6, also mounted on top of the car.

The first antenna is operationally connected with a second antenna 7, mounted on top of the shaft 1. The second antenna is connected by means of a coaxial cable 8 to a third antenna 9, mounted for example on the roof of the building in which the elevator is installed. The first and second antenna are preferably highly directional patch antennas, having an emission angle of at the most 30°, as shown in figure 8. With such an emission angle, the radiation lobe of the antenna is limited within the elevator shaft 1 and absorption of the antenna signal by the walls of the shaft is limited, thus limiting the reflection and the loss of transmission energy. Such patch antennas are known as such and are

for example used in portable GPS (Global Positioning Systems). The third antenna is preferably a yagi antenna, which is also highly directional. The third antenna is preferably installed in such a manner as to be oriented towards a mobile communication antenna, and provided in order to obtain an optimal communication. Yagi antennas are also known as such and for example used for UHF television reception.

It should be noted that the use of this antenna set-up is not limited to the radio transmission of data collected by the device 5 according to the invention and can be used for other purposes such as for example for mobile phone communication. The signal, emitted by the mobile phone of a user inside the elevator car, is then picked up by antenna 6 and emitted towards antenna 7. The latter then picks up that mobile phone signal, transmits it to antenna 9, where it is then emitted towards the receiving antenna of the network. An improved mobile phone communication can thus be obtained inside the elevator car, since the loss of signal, due to absorption by the shaft, is considerably reduced.

The device according to the present invention comprises a buffer memory 10, preferably a ring buffer memory, such as illustrated in figure 2. The buffer memory 10 is connected to a measuring unit 11, provided for measuring a parameter value of a parameter, indicating at least a vertical movement of the elevator car 2. The measuring unit is for example formed by an accelerometer or a velocity-meter, which measures the acceleration or the velocity of the elevator car as said parameter indicates a movement of the car. Preferably, the measuring units measure the movement in three dimensions X, Y, Z such as illustrated in figure 3, which illustrates the acceleration of an elevator car such as measured by the measuring unit. As can be seen from this figure 3, the acceleration is continuously measured during the complete travel

of the car and even before the car started to travel and after the car stopped.

The use of a ring buffer memory 10, has the advantage that no particular addressing of the memory is required, since the latter is rewritten in a cyclical manner. The measuring unit 11, is thus entitled to continuously furnish data to the buffer memory 10, where they will be temporarily stored. Data representing parameter values of successive travels of the elevator car are thus supplied to the buffer memory. Every time that the buffer memory starts a new write cycle, the stored data is overwritten.

The buffer memory 10 is connected to a recognition unit 12, which each time receives a first set of successive parameter values, measured by the measuring unit 11 and temporarily stored in the buffer memory. The recognition unit comprises a local memory for storing a second set of parameter values. The recognition unit is provided for carrying out a matching operation between the first and second set as will be described hereinafter.

The buffer memory 10 and the recognition unit are further connected to a data processor 13, which is connected to a memory 14. An output of the memory is optionally connected to a transmitter module 15, connected with the first antenna 6 and provided for modulating data on a carrier wave in order to enable transmission via for example a mobile communication network.

As illustrated in figure 3, the measuring unit, in this example, a three dimensional accelerometer, measures the acceleration of the elevator car in the X, Y and Z direction. As the Z-direction is the one of the vertical movement, the signal is of course the strongest in that direction. The accelerometer signal of an elevator ride, comprises signatures from the motion of the car, the doors, the passengers and

other vibrations and comprises therefore relevant data for monitoring the elevator. Preferably, the measuring unit comprises a filter, for example a 1 second average filter, in order to reduce the noise present in the measured signal. The curve illustrated on top of figure 3, illustrates the filtered Z-signal. This curve shows a first peak 20, indicating that one or more persons stepped into the car. The second peak 21, shows the acceleration of the departure of the car, whereas the third peak 22 shows the breaking of the car upon reaching the destination floor. Between the second and third peak, the acceleration value remains substantially close to zero since the elevator car principally travels at constant speed. A fourth peak 23 is observed subsequent to the third peak 22 and indicates that the persons step out of the elevator car.

The succession of those four peaks 20 to 23 is a clear indication that the elevator car has made a complete travel between two floors and that relevant data is available. In order to enable a digital storage of this data, the measuring unit is provided with a sampling member operating at a sampling frequency of for example 250Hz. Upon sampling, the measured acceleration signal such as for example the Z-signal illustrated in figure 3, a first set of successively measured acceleration values is obtained. That first set then comprises the four peak values as well as the values in between the peaks. The first set is then supplied to the buffer memory where it is temporarily stored.

In the local memory of the recognition unit 12, a second set of parameter values, identifying a travel of the elevator car is stored. If the measuring unit is an accelerometer, of course the second set will comprise accelerometer values, since the recognition unit is provided to perform a matching operation between the first set stored in the buffer memory and the second set stored in the local memory. The second set

will thus have to be configured according to a similar pattern as the first set in order to enable a suitable matching operation.

The recognition unit compares the first and second set with each other in order to verify if they match, thus indicating that the first set indeed corresponds to a travel of the car. If both signals match, a trigger signal is generated by the recognition unit and supplied to the data processing unit 13, causing the latter to retrieve the first set from the buffer memory. In such a manner, only relevant data is retrieved from the buffer memory and stored into memory 14. If no trigger signal is generated by the recognition unit, which signifies that no relevant data is available in the buffer memory, that data is not retrieved from the buffer memory and it will be overwritten by successive measured data.

The recognition unit thus enables to select among the measured parameter values only the relevant one and to ignore the rest, thus considerably reducing the amount of data to be stored and/or transmitted. Irrelevant data could be generated by jumping into the elevator car when the latter stands still or due to openings or closings of the doors etc.. All that irrelevant data needs not to be processed and can hence be ignored.

The matching operation performed by the recognition unit can be realised either by comparing the data of the first and second set, or by verifying if the values present in the first set exceed predetermined thresholds. The matching is performed either on the supplied data as such, or by first processing the data of the first set. So for example the jerk $j(t)=\frac{da(t)}{dt}$ i.e the rate of change of the acceleration could be considered, or the velocity, the running time, the floor level and the vertical vibration could be considered. Fig. 4 illustrates the jerk such as

derived from the z-signal of figure 3, whereas figure 5 illustrates the z-velocity obtained by integrating the z-signal of figure 3.

In order to obtain an efficient operation of the recognition unit, the latter could be triggered for example by the actuation of a floor level selection button of the elevator or upon recognition of a start signal furnished to the motor. In such a manner, the recognition unit becomes only operative when relevant data will be produced. This would however require connections and modifications into the control system of the elevator, which poses considerable practical difficulties. It is however important that not only the data of the travel is stored but also the data generated just before and just after the start, respectively the stop, of the elevator car.

The total running time of the car is calculated either on the basis of the location of the second and third peak in the accelerometer signal, or on the basis of the integrated signal. However, the peaks are not necessarily symmetrical and equal in width or have a destined centre. Using the velocity signal would be an alternative solution, as the latter is substantial constant over a large part of the travel.

Floor-level measurements require at least one integration of the accelerometer data. Given the typical velocity and the running time, the level change between two floors may be estimated. If the zero-level drift is low, a second integral for obtaining the distance may also be calculated.

Jerk , the time derivative of the acceleration, is one of the quantities which determines the passenger's ride comfort. The initial jerk signature can also say something about the mechanical status of the elevator. The jerk can be calculated from low pass filtered acceleration data for example a 10 Hz 2 pole Butterworth filter, using 0.5 s duration

running best fit lines. As an example of this technique, the jerk signal from the same elevator as the data in figure 2, is shown in figure 6.

In order to determine the vertical vibration of the elevator car, one or more frequency-weighting characteristics are required. The frequency-weighting function with relevance for vertical vibration that affects the whole body in a range from 1Hz to 80 Hz is given by the expression $|H_z| = \left| \frac{0,42 + px45}{1 + px44 + (px30)^2} \right| \approx \sqrt{\frac{0.18 + (f/3.54)^2}{\left[1 - f^2/(8x3.54)\right]^2 + (f/3.62)^2}}$

wherein p is the imaginary angular frequency j2πf in the frequency domain, in reciprocal seconds, and f is frequency in Hz. The numbers in the first expression associated with the angular frequency are given in ms. The numbers in the second expression are given in Hz, and are slightly rounded.

The weighting function is used together with a band-pass filter defined as : $|H_{bp}| = \left[1 + \left(\frac{10^{0.1N_l} x10^{-0.1}}{f}\right)^4\right]^{-0.5} \left[1 + \left(\frac{fx10^{-0.1}}{10^{0.1N_u}}\right)^4\right]^{-0.5}$.

The lower and upper band limiting frequencies are given through the integers N_l and N_u. These are 0 and 19 respectively for the weighting function above. The combined response of the filter and the frequency weighting is seen in figure 7. In the figure it is clearly seen that the maximum response is at about 5 Hz. The used algorithm first identifies the first three zero crossings 26, 27 and 28 (as shown in figure 6) of the weighted signal and then provides the maximum and minimum signal in this interval.

All those values could be used for the matching such as performed by the recognition unit. Depending on the required accuracy level one or more of those values could be selected.

The data obtained by using the device according to the present invention may be used for determining histograms as shown in figures 9 and 10. Figure 9 shows an example of a first histogram illustrating, for a plurality of runs of the elevator car, the number of runs of the elevator car in function of the elevator runtime. This can be achieved either by providing the data processor 13 of the device with a clock for determining the duration of the retrieved signal for each run of the elevator or by counting the duration between the peaks 21 and 22 (figure 3). Assume, for example, that the runtime of the elevator car is 5 seconds per floor. This means that when the elevator car travels during 15 seconds, it will run for 3 floors. By counting during a predetermined period, for example 24 hours, the number of runs for each runtime, the histogram according to figure 9 is for example obtained. Figure 9 shows thus that the elevator has run 30 times during 5 seconds (corresponding to floor), 20 times during 10 seconds (corresponding to two floors), 15 times during 15 seconds (corresponding to three floors) and 10 times during 20 seconds (corresponding to four floors). This histogram may also be sent as data to the remote station. Based on that histogram, useful information can be deduced such as total runtime duration (for maintenance purposes) and failures, such as starting failures (to be deduced from peak 27), stopping accuracy at the floors (to be deduced from peaks 28 and 29) and stopping between two floors (to be deduced from small peak 30).

In Figure 10, there is shown an example of a second histogram according to the invention illustrating, for a plurality of runs of the elevator car, the number of runs of the elevator car in function of the time of the day. This can again easily be achieved by providing the data processor 13 of the device with a clock for determining the time when the signal is retrieved for each run of the elevator. By accumulating during a

predetermined period, for example 1 month, the number of runs in function of a predetermined time pattern, for example the time of the day, possibly in combination with a day of the week, the histogram according to figure 10 is for example obtained. This histogram may further be sent as data to the remote station. Based on that histogram, useful statistical information can be deduced such as traffic pattern. Figure 10 shows for example that the elevator is most used between 4 and 6 p.m. (16 and 18 hours) and also between 7:45 and 9:30 a.m. and between 11 a.m. and 12:45 p.m. Based on such statistics, malfunctions may be detected if for example, during a certain period within peak hours, the elevator is not working, for example due to overheating.

CLAIMS

1. A device for monitoring the operation of an elevator car, said device comprising a measuring unit, provided for measuring a parameter value of a parameter, indicating at least a vertical movement of the elevator car, and a processing unit, provided for processing said parameter value, characterised in that said measuring unit comprises a buffer memory, provided for temporarily storing a first set of successively measured parameter values, said device further comprises a recognition unit, provided with a local memory for storing a second set of parameter values, identifying a travel of the elevator car, said recognition unit being further provided for retrieving said first set from the buffer memory and for performing a matching operation on the first and second set and for generating a trigger signal when said first set matches with said second set, said recognition unit being connected with said processing unit, which is provided for retrieving said first set from said buffer memory under control of said trigger signal.

2. A device as claimed in claim 1, characterised in that said buffer memory is a ring buffer memory.

3. A device as claimed in claim 1 or 2, characterised in that said measuring unit comprises a sampling member, provided for sampling a measured signal, generated by said measuring unit, and forming said parameter value as a result of said sampling.

4. A device as claimed in anyone of the claims 1 to 3, characterised in that said measuring unit comprises an accelerometer and wherein said second set comprises a number of threshold values.

5. A device as claimed in anyone of the claims 1 to 4, characterised in that said processing unit is connected with a data transmission unit, comprising a first directional antenna, provided to be mounted on top of the elevator car, and a second directional antenna,

provided to be mounted on top of an elevator shaft, said first and second antenna being operatively connectable to each other for enabling transmission within the shaft, said second antenna being operatively connectable with a third directional antenna, provided to be mounted on an outer wall.

6. A device as claimed in claim 5, characterised in that said first and second antenna are patch antennas having an emission angle of at most 30°.

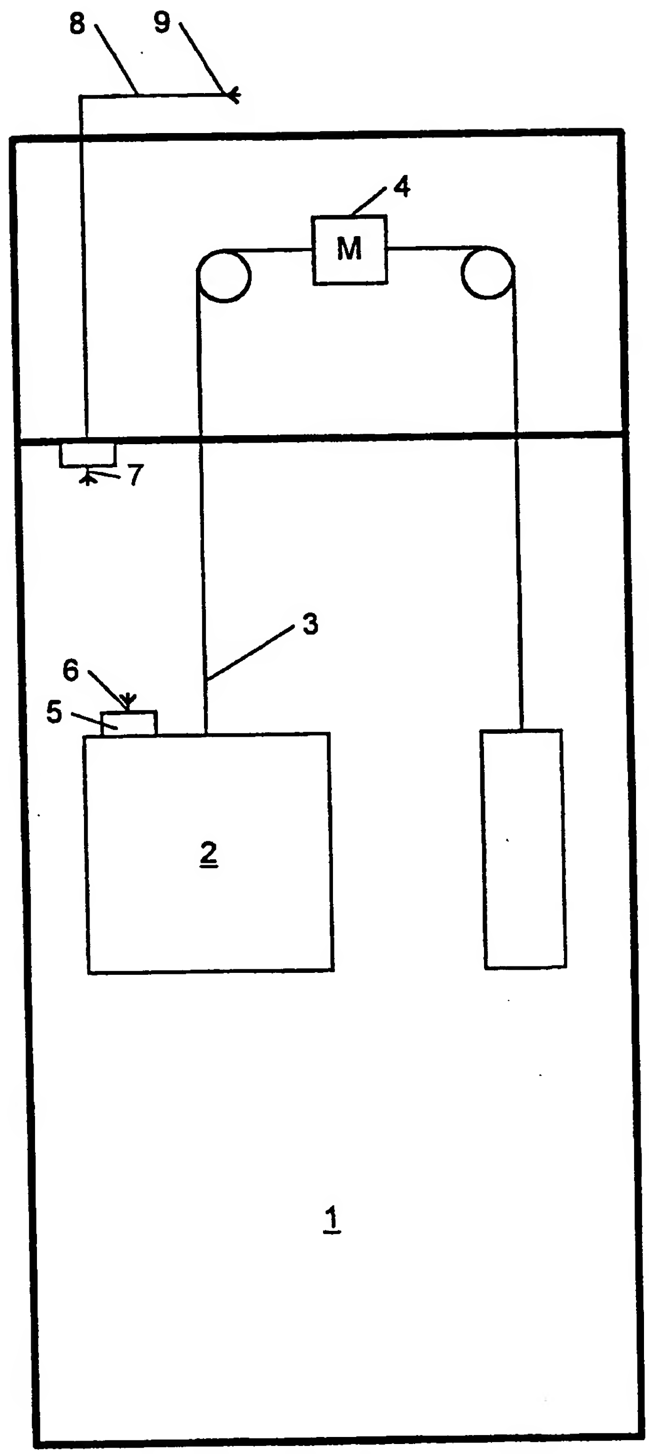


Fig. 1

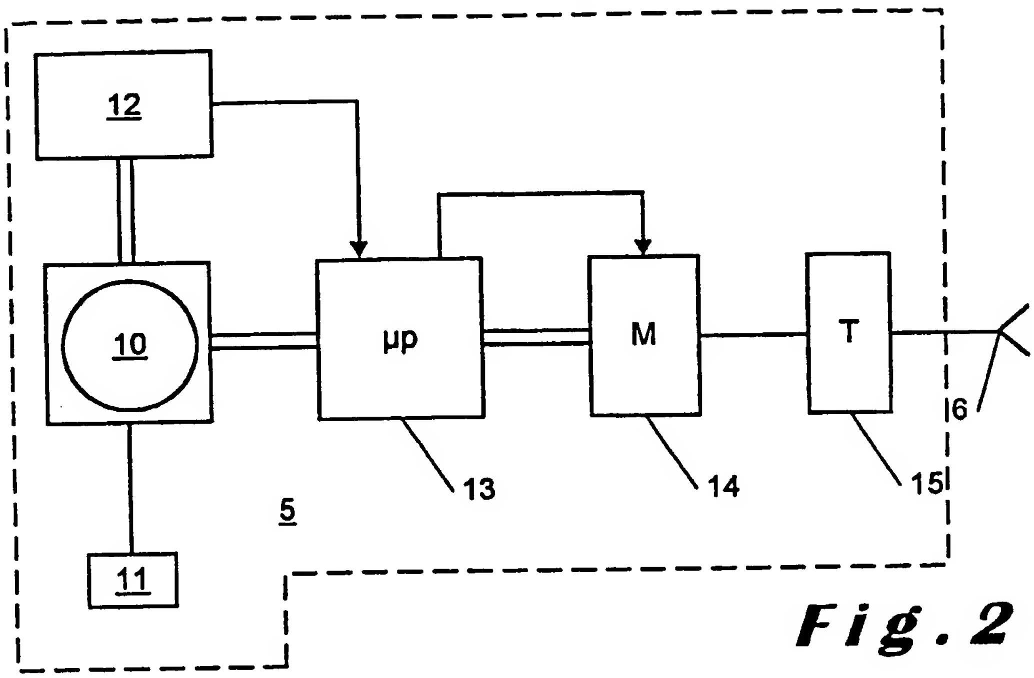


Fig. 2

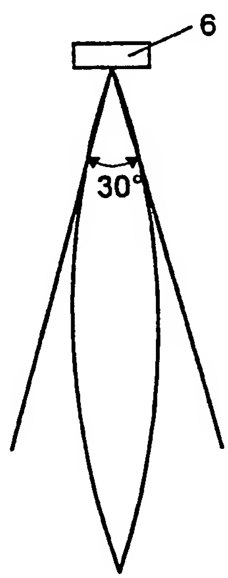
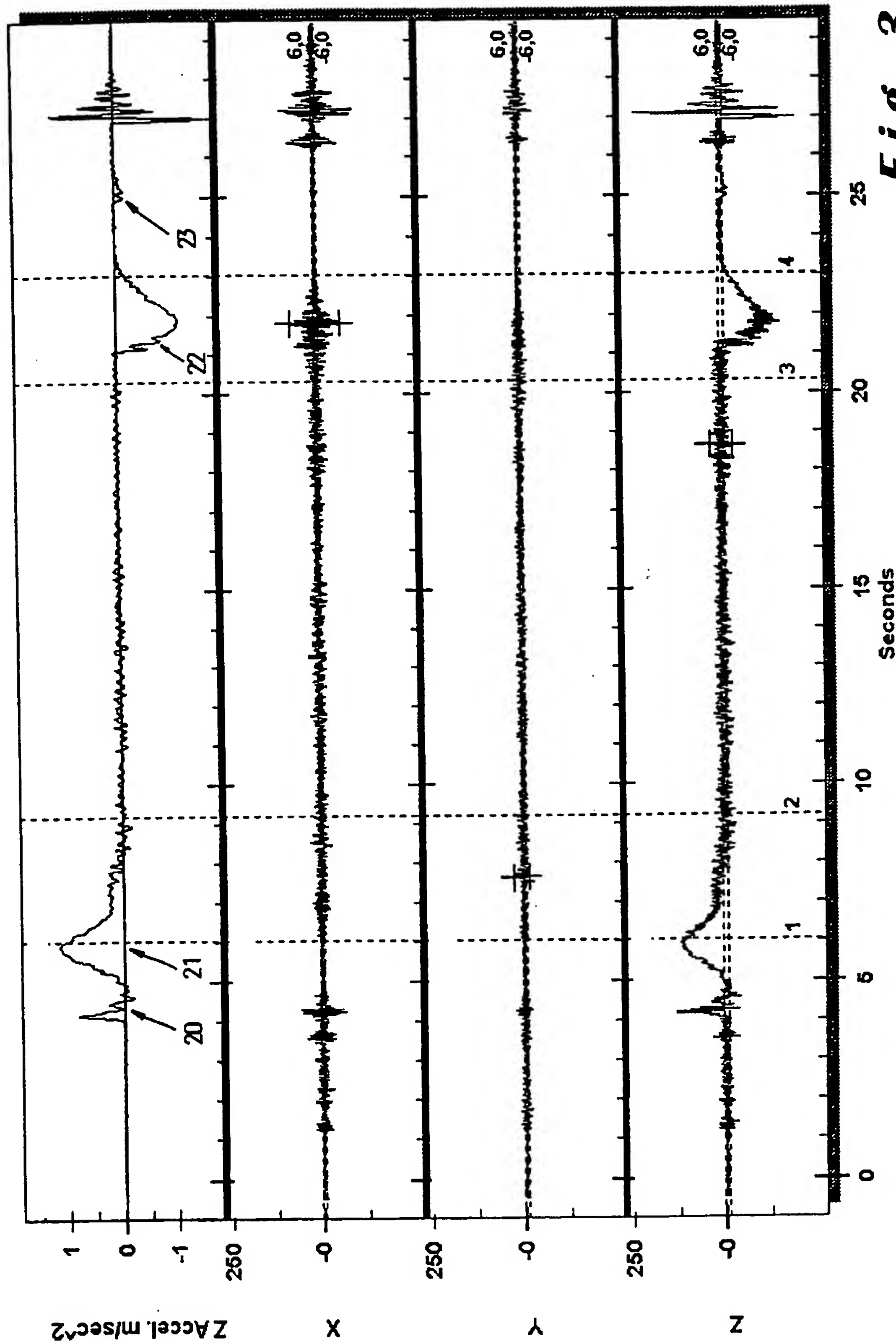


Fig. 8


Z Accel. m/sec^2
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Y
Z
Seconds
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10
15
20
25
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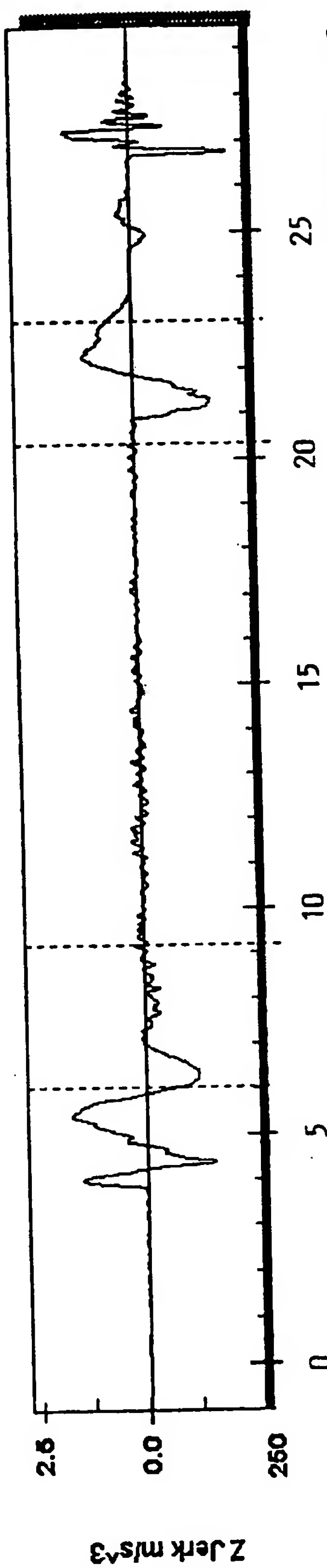
-6,0
1
0
-1
20
21
22
23
1
2
3
4

Fig. 3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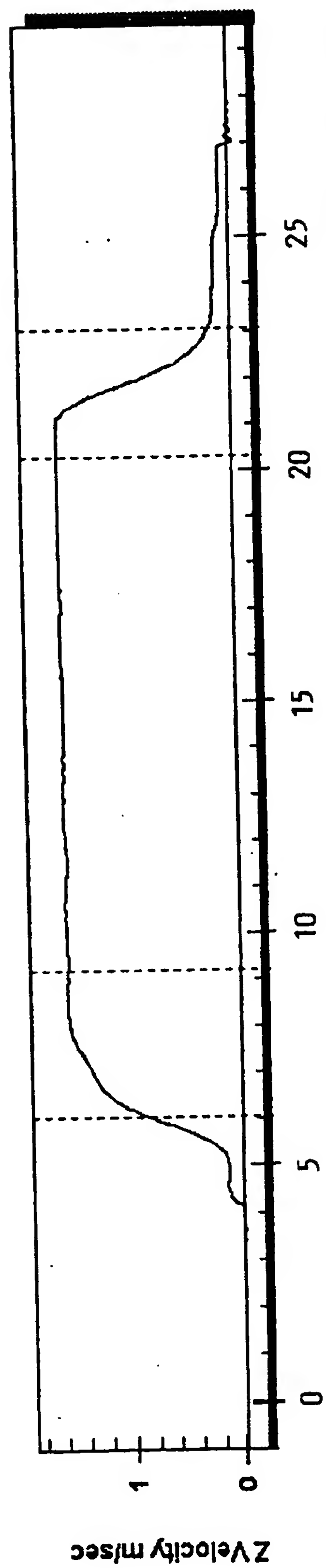
5
10
15
20
25

Fig. 4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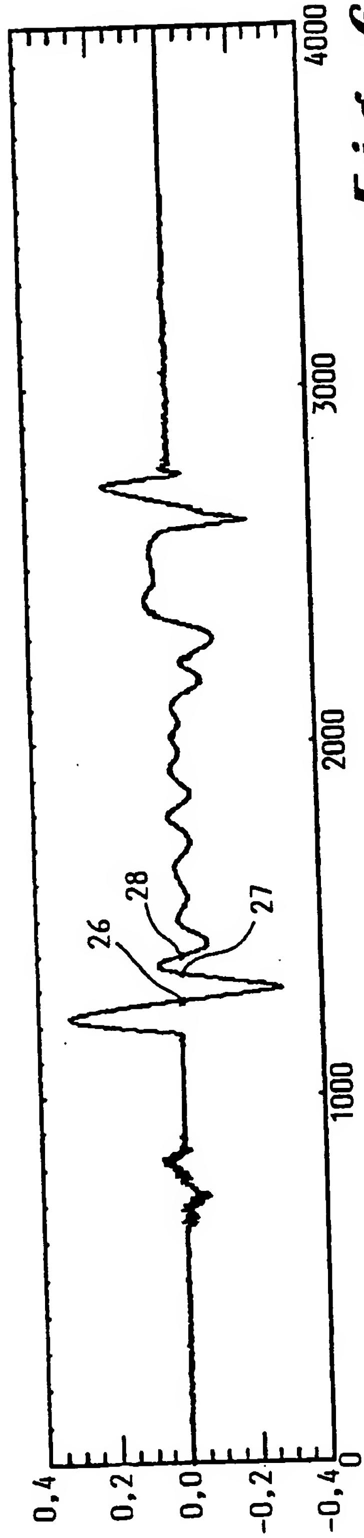
0
0
5
10
15
20
25

Fig. 5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3000
4000
26
27
28

Fig. 6

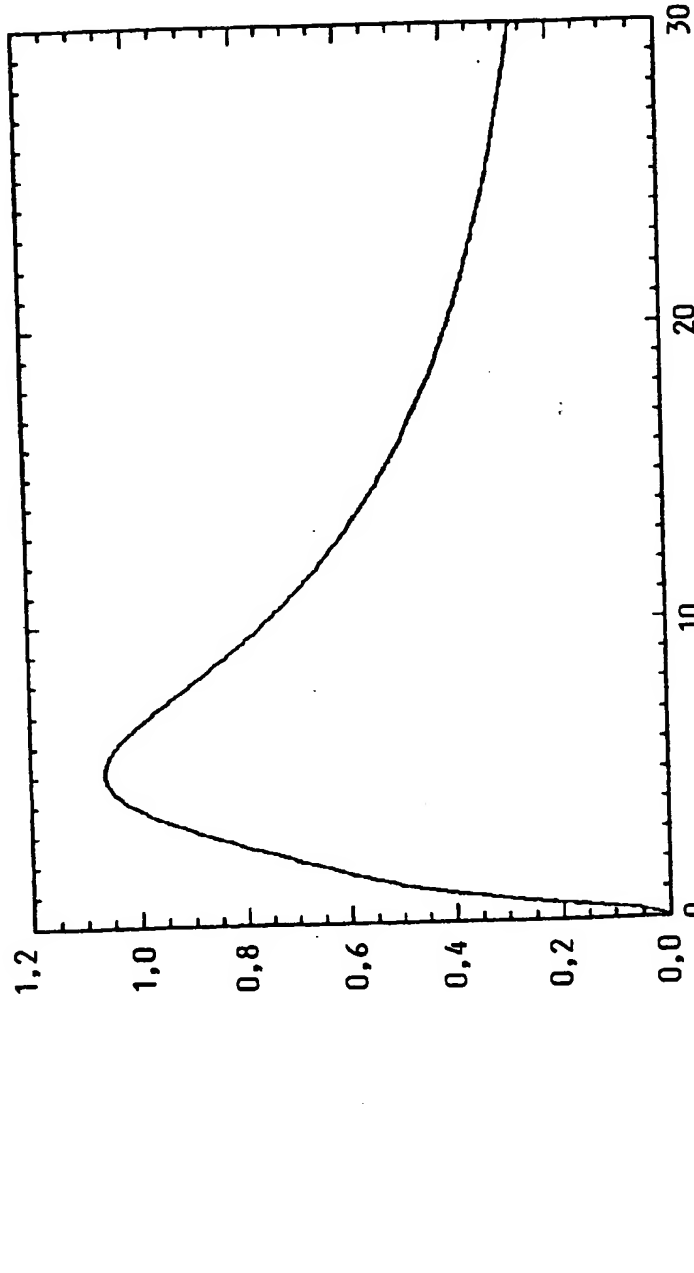
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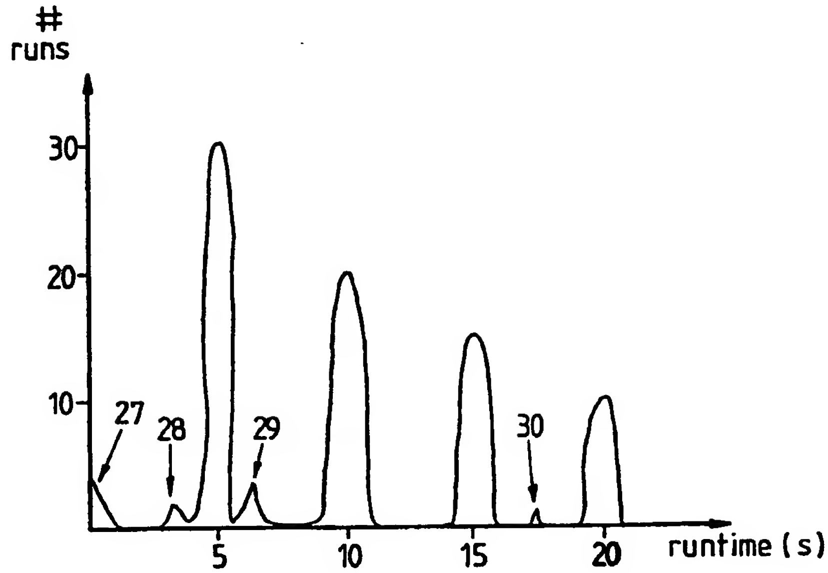
Fig. 7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27
28
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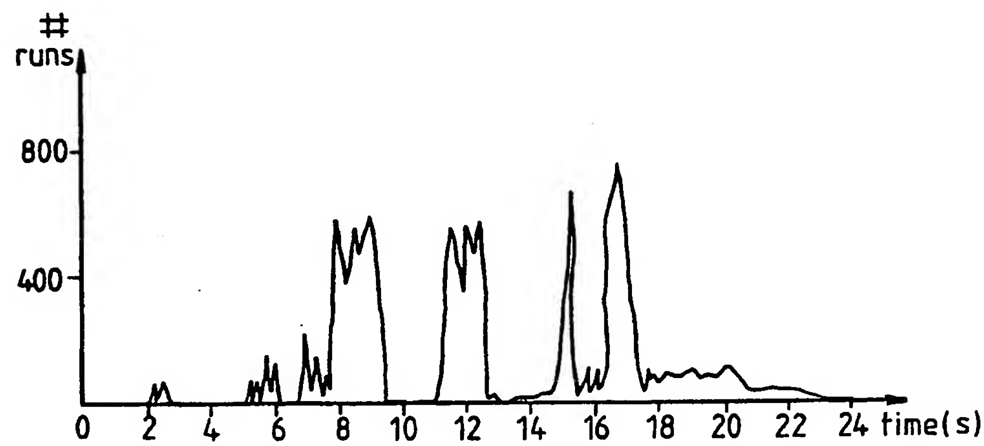
15
20
runtime (s)

Fig. 9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runs
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400
0
2
4
6
8
10
12
14
16
18
20
22
24
time(s)

Fig. 10

INTERNA' NAL SEARCH REPORT

Interna... Application No
PCT/BE 99/00114

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B66B5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B66B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 10, 31 August 1998 (1998-08-31) & JP 10 114478 A (HITACHI BUILDING SYST CO LTD), 6 May 1998 (1998-05-06) -&JP-A-10114478 abstract; figures 1,5	1,3-5
Y	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 04, 30 April 1996 (1996-04-30) & JP 07 323972 A (HITACHI BUILDING SYST ENG & SERVICE CO LTD), 12 December 1995 (1995-12-12) abstract	1,3,4

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 June 2000	14/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Tran-Tien, T

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Inte. .al Application No
PCT/BE 99/00114

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 222 (M-1404), 7 May 1993 (1993-05-07) & JP 04 354777 A (HITACHI BUILDING SYST ENG & SERVICE CO LTD), 9 December 1992 (1992-12-09) abstract	5
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